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TECHNICAL REPORT
70-48-FL

STORAGE LIFE OF LETTUCE AS AFFECTED BY CONTROLLED ATMOSPHERE SYSTEM

by

Abdul R. Rahman
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January 1970

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

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2270.3

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Foreword

Spoilage has been reported in lettuce shipped to Military installations overseas. Causes for the spoilage included slime, decay, mold, and discoloration. An investigation has been conducted on the effect of Oxytrol* modified atmosphere system, used for the transportation of fresh lettuce in refrigerated containers, on shelf life and overall quality.

This work was performed under Production Engineering Project, 2270.3.

The authors wish to acknowledge the assistance of Dr. Thomas White and the Oxytrol Corporation, Burlingame, California, for providing the Oxytrol containers, the nitrogen gas and one lettuce shipment from California to Boston. Acknowledgement is also due to Mr. O Stark for his assistance in the gas analysis and L. Dame for his monitoring of the equipment.

"Tradenames and manufacturing names are used in this report for identification purposes only and such use does not constitute indorsement or approval of any particular product, process or manufacture."

* Oxytrol is a registered Trademark of Occidental Petroleum Corporation.

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ABSTRACT

The effect of Oxytrol controlled atmosphere system on the shelf life of lettuce was evaluated. Lettuce stored under Oxytrol at oxygen levels ranging from 3 to 5.8 percent and temperatures from 34 to 36°F for 2 to 7 weeks gave significantly higher edible yield and showed higher mean scores for overall quality than lettuce stored under normal atmosphere at similar temperatures.

INTRODUCTION

The procurement and supply of fresh produce to the Military Services overseas represents a sizable investment particularly when one considers not only the aquisition cost but also the cost of inspection, transportation, cold storage and distribution to the customer. The supply of high quality produce to the overseas customer is essential both for morale purposes and for good nutrition. However, reports continue to be received of spoilage of produce, particularly lettuce, at overseas supply points. Spoilage of lettuce is a problem which has existed for many years. Although significant improvements have been made in packaging, refrigeration, and controlled atmosphere shipping. Spoilage losses are still encountered in lettuce shipped overseas.

REVIEW OF LITERATURE

A significant amount of research has been conducted in an attempt to prolong the shelf life of fresh produce. The bulk of this research was directed toward civilian market requirements of 1-2 weeks. However, recent work was conducted involving longer storage periods ranging from 4 to 8 weeks to meet the military requirements for shipping lettuce and other fresh produce overseas.

Effects of refrigeration temperature, packaging, chemical additives, and controlled atmosphere on the shelf life of lettuce have been reported in the literature. The deterioration of lettuce is affected primarily by temperature, relative humidity and spoilage organisms. However, russet spotting and pink rib, which appear to be nonpathogenic, frequently cause severe losses even when lettuce is held under desirable transit or storage conditions (Lipton, 1961). When trimmed lettuce was stored in lined crates at 35°F. for 6 weeks, 81 percent remained edible in contrast to 61 percent of untrimmed lettuce stored in unlined crates which was edible. Lettuce retained good quality for considerably longer periods at 32°F. than at 38°F. or 45°F., regardless of the packaging materials. However, packaging with polyethylene bags was the most effective at maintaining good quality (Parsons, 1959, 1965).

Recommendations have been made that lettuce should be held at temperatures as near 32°F. as possible during the entire marketing period, since the rate of deterioration increases rapidly as temperatures rise. It is about five times greater at 75°F. than at 32°F. (Lipton 1965 and Pratt 1954). Stewart and Harvey (1967) found that the quality of lettuce at the time of unloading varied inversely with the temperature at which the lettuce had been maintained during the test. Lettuce maintained at 35°F. to 37°F. was rated "excellent" but that maintained at 38°F. or 39°F. was rated only "good". Bratley (1945) reported a disorder described as "a browning of interior leaves" observed in western grown lettuce. This may have been russet spotting, since after 6 weeks storage at 34°F. russet spotting likely would be present. Rood (1956) indicated that russet spotting can be induced artificially be exposing head lettuce to ethylene.

Results of research on the effect of controlled atmosphere on the quality of lettuce vary. Controlled atmosphere tests with lettuce showed no effects from storage in oxygen concentrations as low as 1 percent for up to 8 days at 41°F. High concentrations of carbon dioxide, however, were harmful to lettuce (Watada, 1964). Lettuce stored at 33°F., and held at 1 or 0 percent oxygen developed less russet spotting than lettuce held in air (Parsons, 1964). Littlefield et. al. (1966) reported that controlled atmospheres, within the limits of concentrations usable for fruit storage (2 percent oxygen and 2-11.5 percent CO_2), are effective fungestatic agents.

Some definite, but limited, benefits have been derived from the use of certain low O_2 atmospheres under conditions simulating the transcontinental shipment of head lettuce. The substantial reduction in russet spotting, even at O_2 concentrations as high as 8 percent, is clearly the major benefit. However, O_2 levels at 0.5 percent or lower during storage within the temperature range studied (36°F. to 50°F.), sometimes injured the heart leaves (Lipton, 1967).

Lugg (1969) stated that the use of carbon monoxide (.25 to .50 percent), in conjunction with low oxygen levels, would significantly retard butt end discoloration of lettuce. However, the expense of maintaining this level of CO with on-board tanks was expensive. But when modified atmospheres are used correctly on fruits and vegetables it was economically advantageous by providing a longer shelf life. White (1968) indicated that low oxygen levels significantly reduced decay and improved overall appearance of lettuce after 28 days of storage. Low O_2 atmospheres (3.3-3.8 percent) in liquid nitrogen refrigerated piggyback trailers significantly reduced russet spotting. Decay and butt discoloration were slightly less severe in lettuce from the nitrogen refrigerated trailer than that from the mechanically refrigerated trailers (Steward, 1968).

El-Mansy (1967) indicated that the post harvest treatment of lettuce with 6-furfurylaminopurine extended shelf life beyond that of the untreated. Gorfien et al. (1969) stated that when controlled atmospheres were maintained, significant improvements in quality and storage life were obtained. Reduction in slime, pink rib and russet spotting were found.

EXPERIMENTAL PROCEDURES

Four different experiments using different crops of Iceberg lettuce were conducted during the course of this study. The lettuce was stored in containers using the Oxytrol system. This system is a complete, self-contained atmosphere control system designed to be used as an adjunct to normal refrigeration equipment in conventional transport vehicles. These containers are designed for shipment or fixed storage of perishable commodities under low oxygen atmospheres. Liquid nitrogen is used to reduce the oxygen level. The container is insulated and equipped with a refrigeration unit to control temperature. A supply of liquid nitrogen is carried in a portable Linde LS-160B container (Figure 1). Automatic operation of the N_2 flow is provided by the special controls in the system.

The lettuce was tested at intervals ranging from 3 to 10 days by three experienced judges using the following procedure:

a. Overall appearance - using a 9-point scale (9 = Field fresh; 1 = Inedible) (Figure 2).

b. Defects, such as decay, pink rib, russet spotting, using a 9-point scale (9 = defects absent; 1 = severe) (Figure 2).

c. Edible yield, determined by removing the butts as well as the defective parts of the lettuce head and weighing the remainder as the edible portion. This was divided by the original weight to obtain percent edible yield.

Oxygen levels were monitored during the experiments. A representative sample of the atmosphere in the controlled atmosphere container was analyzed chromatographically weekly. After the sample was taken, the container door was opened for few minutes to check the voltage of the oxygen analyser controller.

Experiment No. 1 - Lettuce (16 boxes; 24 heads per box) was obtained the day of harvest at Salinas, California, vacuum cooled, and shipped to the U.S. Army Natick Laboratories in two refrigerated trailers. One was equipped with Oxytrol controlled atmosphere units set at 4% oxygen. Half the lettuce in each trailer was trimmed, wrapped in polystyrene film and packed in perforated fiberboard boxes. The remainder of the lettuce was untrimmed, unwrapped and packed in slotted fiberboard boxes. The temperature of the trailers was set at 35 $\pm$ 2°F. The pulp temperature of the lettuce upon arrival was 38°F. Shipping time was seven days. The 16 boxes of lettuce represented the following variables:

a. Trimmed, wrapped lettuce shipped via Oxytrol system.

b. Untrimmed, unwrapped lettuce shipped via Oxytrol system.

c. Trimmed, wrapped lettuce shipped via refrigerated trailer.

d. Untrimmed, unwrapped lettuce shipped via refrigerated trailer.

Upon receipt, the lettuce was stored in two containers 72" long, 32" wide and 89" high. The 8 boxes shipped in Oxytrol trailers were placed in an Oxytrol test container and 8 boxes shipped in normal atmosphere trailers were placed in a normal atmosphere test container. The temperature for both containers was set at 34°F. and the oxygen level in the Oxytrol controlled atmosphere container was set at 5 percent. The duration of this experiment was seven weeks, the first five in Oxytrol containers with controlled atmosphere and then two weeks in walk-in chill box at 40°F. under normal atmosphere.

Experiment No. 2- Sixteen fiberboard cartons of naked pack (untrimmed, unwrapped) lettuce, grown in Arizona, was procured locally. The lettuce had been shipped in refrigerated containers. The lettuce was placed in a walk-in 40°F. chill box for 17 days, then placed in the Oxytrol containers at 34°F. with the oxygen level at 5 percent for 22 days.

Experiment No. 3 - Sixteen boxes of naked pack (untrimmed, unwrapped) lettuce grown in California and shipped in refrigerated trailers were purchased locally. The lettuce was placed in Oxytrol containers at 34°F. with oxygen level at 5 percent for 14 days. It was then transferred to a walk-in 40°F. chill box for 22 days.

Experiment No. 4 - Naked pack (untrimmed, unwrapped) lettuce grown in Arizona and shipped in refrigerated trailers was purchased locally. The lettuce was placed in the Oxytrol containers at 34°F. with oxygen level at 5 percent. Storage was for six weeks. The doors of the containers were opened for a few minutes at the end of each of the first two weeks to check the voltage of the oxygen analyser controller. During the last four weeks, the doors were not opened at all to determine whether the Oxygen level would drop to below 1 percent. A perforated paper bag containing two pounds of quick lime was placed in each container in order to reduce the CO_2 content.

RESULTS AND DISCUSSION

Results of experiments conducted on the storage of 4 different lettuce crops for periods from 2 to 7 weeks are shown in Tables 1, 2, 3 and 4. They indicate that lettuce stored under Oxytrol C.A. (Controlled atmosphere) where O2 level ranged form 3 to 5.8 percent and temperatures ranged from 34°-36°F.* showed significantly higher edible yield than the ones stored under normal atmosphere at similar temperatures. Mean scores for general appearance and defects in terms of slime, mold, russet spotting, pink rib and other discolorations were higher for lettuce stored under Oxytrol controlled atmosphere system than the ones stored under normal atmosphere.

The results of experiment No. 1 are shown in Table 1. The wrapped and unwrapped field fresh lettuce stored 6 weeks after picking under normal atmosphere was a total loss, whereas 28.8 percent edible yield for unwrapped and 60.6 percent for wrapped lettuce were obtained under Oxytrol C.A. Furthermore, upon extending the storage period to 7 weeks after picking, 16.0 and 21.4 percent edible yield were obtained for unwrapped and wrapped lettuce, respectively. In general, wrapped lettuce gave higher edible yield than the unwrapped. Figure 5 shows the condition of lettuce stored 5 weeks after picking.

Results of experiment No. 2 (Table 2) indicate that lettuce stored for 17 days at 40°F and followed by storage for 22 days under Oxytrol CA showed higher mean scores for overall quality and gave significantly higher edible yield than that stored under normal atmosphere for 31 days. After 39 days, lettuce stored under normal atmosphere was a total loss, whereas 35.8 percent edible yield was obtained form lettuce stored under Oxytrol C.A.

* Although the O_2 control system was set at 4 and 5 percent, the chemical analysis indicated a range of 3-5.8%. Temperatures fluctuated between 34° and 36°F, although the control was set at 34°F.

Results of experiment No. 3 (Table 3) indicate that lettuce stored for 14 days under Oxytrol C.A. followed by 20 days at 40°F. under normal atmosphere showed higher mean scores for overall quality and gave significantly higher edible yield than the ones stored at similar temperatures under normal atmosphere.

Results of experiment No. 4 (Table 4) indicate that after six weeks of storage at 34-36°F. under normal atmosphere the lettuce was completely inedible, whereas 12.5 percent of edible yield was obtained from lettuce stored under Oxytrol C.A.

When the Oxytrol system was unopened for 4 weeks, the O_2 level dropped to 3 percent. This did not constitute an unaerobic condition.

Keeping time of up to 7 weeks under Oxytrol C.A. system is sufficient to meet anticipated overseas shipping time requirements.

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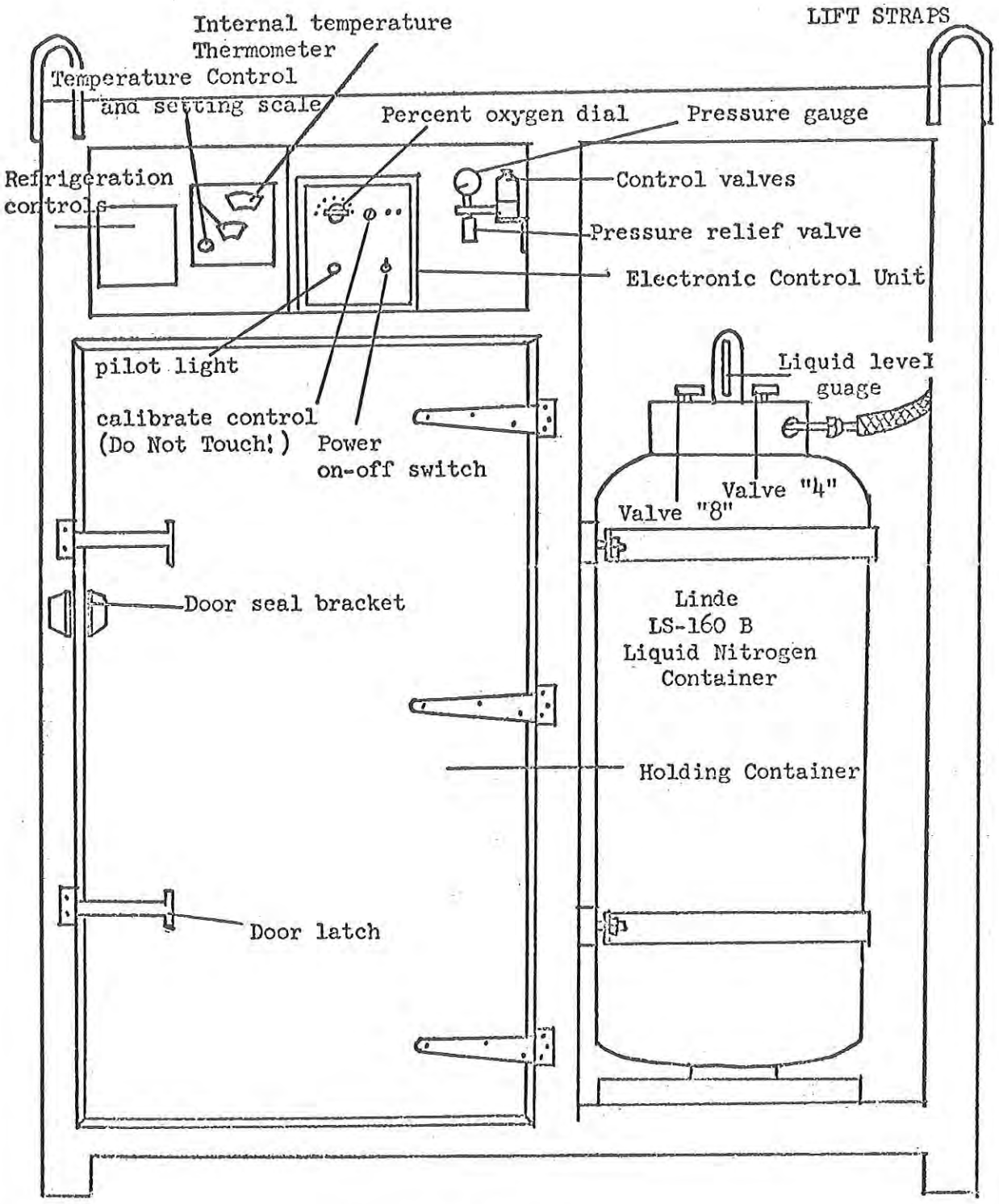

Figure 1.

FRONT VIEW - OXYTROL MODEL 050 PORTABLE CONTAINER - OPERATING CONTROLS

LETTUCE EVALUATION
TEST # _____

SCORING CRITERIA

O.A. (W.W.L) = Overall Appearance - With Wrapper Leaves

O.A. (Trimmed) = Overall Appearance - Trimmed

* Field Fresh		Good-Minor Defects		Fair-Removable Defects		Poor-Generally Unsalable		In-edible
9	8	7	6	5	4	3	2	1

Decay - Pink Rib - Russet Spotting

Defects Absent		Trace		Slight		Moderate		Severe
9	8	7	6	5	4	3	2	1

Date _____

Duration _____

Treatment _____

Carton # _____

Chamber # _____

Name _____

DEFECTS	Top Layer												Bottom Layer											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
O.A. (W.W.L)																								
O.A. (Trimmed)																								
Decay (Slime, mold, etc.)																								
Pink Rib																								
Russet Spotting																								

* The following are considered defects: Discoloration such as browning, darkening, black, pink, red spotting or the presence of any color not typical of the fresh product; physical damage such as bruises and skin breakage; diseases such as mold, slime and soft rot; wrinkled surface; wilt; tip burn; spotting; dehydration and any other sign not typical of the fresh product.

Differences in appearance of butt color _____

_____

Other Comments _____

_____

_____

Figure 2. Technological Evaluation Sheet

Figure 3. Effect of Storage Conditions on the Quality of Lettuce

Unwrapped lettuce stored under Oxytrol Controlled Atmosphere System 5 Weeks after Picking(1 week transit & 4 weeks at NLABS).

Unwrapped lettuce stored under Normal atmosphere at approximately 34°F., 5 weeks after picking(1 week transit & 4 weeks at NLABS).

Wrappped lettuce stored under Oxytrol Controlled Atmosphere System, 5 weeks after picking (1 week transit & 4 weeks at NLABS).

Wrapped lettuce stored under normal atmosphere at approximately 34°F., 5 weeks after picking(1 week transit & 4 weeks at NLABS).

Bottom layer of a 4 fiberboard boxes stack of lettuce stored under normal atmosphere conditions at approximately 34°F., 5 weeks after picking (1 week transit & 4 weeks at NLABS).

Table 1. Effect of Storage Conditions on the Quality of Lettuce Stored 5 to 7 Weeks After Picking

Storage Conditions	Storage Time After Picking	Percent Edible Yield		Mean Technological Scores Defects		Overall Appearance	
	Weeks	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped
Oxytrol 4.4 O_2 at 34°F.	5	66.0*	50.5*	7.0	6.6	8.3	8.0
Normal atmosphere at 34°F.	5	14.2*	12.0*	3.0	2.2	1.3	2.3
Oxytrol 4.5% O_2 at 34°F. for 5 Weeks plus 1 week under normal atmosphere at 40°F.	6	60.6*	28.8*	5.9	4.2	6.0	5.8
Normal atmosphere at 40°F.	6	0*	0*	1	1	1	1
Oxytrol 4.4% O_2 at 34°F.	7	27.5*	27.0*	6.1	6.0	7.1	7.2
Normal atmosphere at 34°F.	7	0*	0*	1	1	1	1
Oxytrol 4.5% O_2 at 34°F. for 5 weeks plus 2 weeks under normal atmosphere at 40°F	7	21.4	16.0	3.9	3.8	4.0	3.9

* Significant at the 1 percent level

Table 2. Effect of Storage Conditions on the Quality of Lettuce Stored for 21 to 39 Days After Purchase

Storage Conditions	Storage Time after purchase	*Percent Edible Yield	Mean Technological Scores	
			Overall Quality	Defects
	Days			
Normal atmosphere at 40°F. for 17 days plus 4 days, Oxytrol 5-8% O_2 at 34°F.	21	60.8*	7.2	7.5
Normal atmosphere at 40°F. plus 4 days at 36°F.	21	55.6*	6.1	6.0
Normal atmosphere at 40°F. for 17 days plus 14 days Oxytrol 5.8% O_2 at 34°F.	31	43.5*	5.3	5.5
Normal atmosphere at 40°F. for 17 days plus 14 days at 34°F.	31	25.3*	4.3	4.1
Normal atmosphere at 40°F for 17 days plus 22 days Oxytrol 5-5% O_2 at 34°F.	39	35.8*	4.3	4.5
Normal atmosphere at 40°F. for 17 days plus 22 days at 34°F.	39	0	1	1

* Significant at the 1 percent level

Table 3. Effect of Storage Conditions on the Quality of Lettuce Stored for 14 to 34 days after Purchase

Storage Conditions	Storage Time after purchase	Percent Edible Yield	Mean Technological Scores	
			Overall Quality	Defects
	Days			
Oxytrol 5-7% O_2 at 34°F.	14	57.4*	8.0	8.3
Normal atmosphere at 34°F.	14	44.4*	7.0	7.4
Oxytrol 5-7% O_2 at 34°F. plus 8 days at 40°F. under normal atmosphere.	22	55.8*	5.3	6.0
Normal atmosphere at 34°F. for 14 days plus 8 days at 40°F.	22	21.0*	3.4	4.0
Oxytrol 5-7% O_2 at 34°F. plus 20 days at 40°F. under normal atmosphere.	34	40.2*	4.9	5.1
Normal atmosphere at 34°F for 14 days plus 20 days at 40°F.	34	10.5*	3.4	3.7

* Significant at the 1 percent level

Table 4. Effect of Storage Conditions on the Quality of Lettuce Stored for 2 to 6 Weeks after Purchase

Storage Conditions	Storage Time after Purchase	Percent Edible Yield	Mean Technological Scores Overall Quality	Defects
	Weeks			
Oxytrol 5-7% O_2 at 34°F.	2	57.4*	7.4	7.3
Normal atmosphere at 34°F.	2	46.5*	7.0	6.8
Oxytrol 3-4% O_2 at 34°F.	6	12.5*	2.5	2.9
Normal atmosphere at 34°F	6	0 *	1	1

* Significant at the 1 percent level.

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Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

US Army Natick Laboratories
Natick, Massachusetts 01760

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

Storage Life of Lettuce as Affected by Controlled Atmosphere System

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

Abdul R. Rahman, Glenn Schafer, George R. Taylor, Donald E. Westcott

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1970	20	17

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 2270.3	70-48-FL
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* FL-106
d.	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	US Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

The effect of Oxytrol controlled atmosphere system on the shelf life of lettuce was evaluated. Lettuce stored under Oxytrol at oxygen levels ranging from 3 to 5.8 percent and temperatures from 34 to 36°F for 2 to 7 weeks gave significantly higher edible yield and showed higher mean scores for overall quality than lettuce stored under normal atmosphere at similar temperatures.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Controlled atmosphere	6		5,10			
Oxytrol system	6		5,10			
Lettuce	7		9			
Storage	7		8,4			
Protection	7		8			
Military bases	4		4			
Transportation	4		8			